BREAST TUMOR EARLY DETECTION USING UWB ANTENNA AND IMPROVED FEATURE EXTRACTION TECHNIQUE

by

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LIST OF ABBREVIATIONS

AI	Artificial intelligence
ANN	Artificial neural network
AWBU	Automated whole breast ultrasound
BT	Breast tomosynthesis
CAD	Computer -aided detection
CE-DBT	Contrast enhanced- digital breast tomosynthesis
CM	C-means
CMI	Confocal microwave imaging
CST	*Computer Simulation Technology*
CWT	Continuous wavelet transform
DAS	Delay-and-sum
DCT	Discrete cosine transform
DFT	Discrete fourier transform
DM	Digital mammography
DMIST	Digital mammographic smaging screen trail
FCC	Federal communications commission
FDTD	Finite difference time domain
FFDM	Full-field digital mammography
FFT	Fast fourier transform
FIT	Finite integration technique
GA	Genetic algorithm
GHz	Giga hertz
GRNN	General regression neural network
ICA	Independent component analysis

KHz	Kilo hertz
KSOM	Kohonen self-organizing map
LDA	Linear discriminate analysis
LMS	Least mean square
mm	Mille mitre
MHz	Mega hertz
MIMO	Multiple input multiple output
MIST	Microwave imaging space-time
MR	Magnetic resonance
MRI	Magnetic resonance imaging
MSE	Mean square error
NN	Neural network
PC	Principle component
PCA	Principle component analysis
PCB	Printed circuit board
PEM	Positron emission mammography
PET	Positron emission tomography
PFA	Principle feature analysis
PNA	Programmable network analyzer
PNN	Probabilistic neural network
RBF	Radial basis function
RCB	Robust capon beam forming
ROC	Receiver characteristic curve
RMS	Root mean square
RS	Rough set
SOM	Self organizing map
SVM	Support vector machine

TSAR	Tissue sensing adaptive radar
UWB	Ultra wide-band
WBAN	Wireless body area network

LIST OF VARIABLES

d_{Tx}	Distance between transmitting antenna and breast model
d_{Rx}	Distance between receiving antenna and breast model
Tx	Transmitter antenna
Rx	Receiver antenna
S_{11}	Reflection co-efficient
S_{21}	Transmission co-efficient
ε	Permittivity
$\overline{\sigma}$	Conductivity
μ	Permeability
w	Weight vector
b	Bias
k	Kernel function
E	Error function
y_n	Actual output
t_n	Target output
ζ	Slack variable
R	Field region
D	Diameter of antenna
λ	Wavelength
ω_o	Frequency of oscillation
ϕ	Cost function

Pengesanan Awal Ketumbuhan pada Payudara Menggunakan Antena UWB dan Penambahbaikan Ciri Teknik Pengekstrakan

ABSTRAK

Kanser payudara telah menyerang wanita dengan kejam di seluruh dunia. Ramai pesakit mempertaruhkan nyawa mereka setiap hari kerana kekurangan teknologi penyembuhan yang cekap dan sejumlah besar pesakit juga sedang berdepan risiko kematian. Pada masa ini, X-ray mammografi diiktiraf sebagai standard terbaik bagi pemeriksaan kanser payudara, tetapi ia mengalami nisbah kesalahan pengesanan yang tinggi, kesakitan mampatan payudara dan lain-lain kesan sampingan yang berbahaya. Tujuan utama kerja-kerja ini adalah untuk mengenal pasti tumor dalam saiz yang kecil dengan menggunakan kaedah pengesanan yang cekap, mesra pengguna dan bukan kaedah pemedahan tanpa kesan sampingan ke atas kesihatan manusia. Untuk mencapai tahap itu, *microstrip patch ultra Wideband* (UWB) antena berbentuk piramid dicadangkan untuk diantara frekuensi 3.23 GHz hingga 12 GHz untuk berasaskan radar sistem pengimejan gelombang mikro. Prestasi antena diukur dalam medium udara dan juga di sekitar model payudara untuk band teknology UWB yang lebih rendah (3 GHz ke 6 GHz). Dalam kedua-dua kes, antena dan pantulan (S_{11}) dan penghantaran (S_{21}) pekali diuji dalam medan dekat dan jauh. Ujikaji dan model payudara realistik juga direka mengggunkan perisian *Computer Simulation Technology* (CST). Jarak (d_{Tx}) di antara pemancaran (Tx) antena dan model payudara diubah dari 1 mm sehingga 36 mm. Keputusan menunjukkan bahawa, antena Tx lebih baik di rantau reaktif berhampiran pada d_{Tx} 1 mm hingga 10 mm dari model payudara. Maksimum dan minimum kehilangan penghantaran direkodkan ialah -63.74 dB dan -9.5 dB masing-masing pada jarah 36 mm dan 1mm. Sebaliknya , kehilangan pantulan maksimum dan minimum yang dicatatkan adalah -1 dB dan -52.58 dB masing-masing pada 36 mm dan 2 mm. Berdasarkan keselurahan eksperimen, penerima diletakkan secara tetap pada 1mm dari payudara dan isyarat yang diterima disimpan untuk pemprosesan isyarat selanjutnya. Satu teknik pengekstrakan cekap dicadangkan. Ia juga meningkatkan rangkaian latihan dan kecekapan ujian neural dengan mengurangkan tempoh masa yang diperlukan . Prestasi keseluruhan sistem disahkan dengan menggunakan dicadangkan pengekstrakan ciri dan antena yang dicadangkan untuk saiz tumor berbeza. Kajian perbandingan antara fungsi kernel *support vector machine* (SVM) termasuk fungsi *linear*, fungsi asas jejarian, polinomial dan persepsi berbilang lapisan dikaji dan dibuktikan untuk pengiktirafan prestasi corak dengan ketepatan 100 %. Tetapi SVM mengesan saiz tumor dengan ketepatan lebih rendah berbanding dengan keputusan *artifical neural network* (ANN). Secara keseluruhan sistem ini dapat mengesan kemujudan tumor bersaiz 1 mm (diameter) dengan ketepatan kira-kira 99% iaitu 3.2% lebih tepat berbanding sistem sedia ada.

Breast Tumor Early Detection using UWB Antenna and Improved Feature Extraction Technique

ABSTRACT

Breast cancer has already invaded the women around the world with its brutal attack. Numerous patients are sacrificing their lives everyday due to lack of efficient cure technology and a huge number of patients are still existing to hear the death sentence. X-ray mammography is currently recognized as the golden standard of breast cancer screening, but it suffers from high miss detection ratio, painful breast compression and other harmful side effects. The main motto of this work is to identify the tumor in its smallest dimension using an efficient, user-friendly and non-invasive detection method without any side effects on human health. Towards this goal, a pyramidal shaped microstrip patch ultra wideband (UWB) antenna is proposed for frequency range of 3.23 GHz to 12 GHz for radar based microwave imaging system. The performance of the antenna is measured in air media as well as in the vicinity of breast model for lower band (3 GHz to 6 GHz) of UWB. In both cases, the antenna's reflection (S_{11}) and transmission (S_{21}) coefficients are investigated in near field and far field region. A realistic breast model is also designed through *Computer Simulation Technology* (CST) software and experimentally. The distance between the transmitting antenna and breast model is varied from 1 mm up to 36 mm. The results show that, the proposed antenna performs better in near reactive region at a distance of 1 mm to 10 mm. Maximum and minimum transmission losses are -63.74 dB and -9.5 dB at 10 mm and 1 mm distance respectively. On the other hand, maximum and minimum reflection losses are found -1 dB and -52.58 dB at 36 mm and 2 mm respectively. In the whole experiment, the receiver is kept fixed at 1 mm apart from the breast and the received signals are reserved for the further signal processing. An efficient feature extraction technique (i.e., maximum, minimum, mean and standard deviation amplitude values of received pulse) is proposed here which also enhances the neural network training and testing performances by reducing the required time duration three times than previous studies. The overall system performance is verified by using proposed feature extraction and proposed antenna for various tumor sizes. The comparative study among support vector machine (SVM) kernel functions including linear function, radial basis function, polynomial and multi layer perceptions are investigated and verified for pattern recognition performance with 100% accuracy. SVM detects tumor size with lesser accuracy than artificial neural network (ANN) results. The overall experimental system with ANN is able to detect tumor existence and tumor size of 1 mm (diameter) with nearly 99 % accuracy, which is around 3.2% more than related existing systems.

CHAPTER 1

INTRODUCTION

1.1 Background

Breast cancer is a fatal disease among the women all over the world. It is recognized as the second deadly cancer after the lung (United States Cancer Statistics, 2010). Researchers are studying more and more to figure out the reason behind this deadly disease. It may apparent that, abnormal cell division of the breast tissues usually occurs either in lobules (milk producing tissue) or in ducts (connecting tissue between lobule and nipple). This abnormal cell division forms mass or lump that is called tumor. There are two types of tumors: benign and malignant. Usually, tumors are benign but with the passage of time, it turns into the deadly cancer called malignant tumor. In a recent survey from American cancer society (American Cancer Society 2012), it is found that 89% of women could survive if the cancer is detected within 5 years, this is also known as early detection. This rate may reduce to about 82% and 77%, if it is detected after 10 years and 15 years respectively. The researches show that early detection is prerequisite for the long term survival (Joy et al., 2005; Taber et al., 2003). To the best of author's knowledge, at present there is no cure method exists in the universe. There are very few available detection techniques to detect breast tumor in early stage. Most of the existing detection techniques have two major shortcomings, which are hazardous to human body and unable to detect in early stage. At present, X-ray mammography is recognized as the golden detection technique for breast cancer (Tabar et al., 2010). This method has some bad effects on human health. Firstly, the required breast compression for the test is painful and harmful to the patient. Secondly, the ionization effect of the mammography may destroy the surrounding healthy breast tissues. Study shows that the mammography may have the miss detection ratio up to 30% (Huynh et al., 1998). Several studies reveal that mammography is more suitable for the non-dense breast rather than the other types. So, it is not a wise approach for woman less than 30 years of old (Saslow et al., 2007) and that is why researchers are looking for a subsidiary option. Ultra sound technology may be a good solution for this issue. This technology uses the ultra sound for detection of breast tumor. But this technique produces very low sensitivity signal. This poor sensitivity may hamper and blur the image quality of the test and confuse physiologists during check-up (Kaplan et al., 2001; Crystal et al., 2003).

Nuclear methods are already introduced for breast cancer detection whereas positron emission mammography (PEM) and positron emission tomography (PET) are mostly used techniques. The most challenging part of this method is the handling risk of nuclear materials. This method is efficient to detect the cancer with some side effects on human body; but frequent use of this technology become hazardous to human body. Microwave imaging has extensively been introduced for biomedical applications. The advantage of this technology having less side effect to human health. Ultra wideband (UWB) technology is one of them and suitable for early detection of breast cancer. It's low power transmission and object detecting capability attracts the researchers to utilize this technology for biomedical applications. According to Federal Communications Commission (FCC), the allocated frequency range for the UWB technology is 3.1 GHz to 10.6 GHz (FCC, 2002). The basic principle of UWB breast imaging is the dielectric properties discrepancy between cancerous and healthy breast tissuea. The cancerous tissues scatter more signal imposed on it than normal tissues (Farhang et al., 2008).

Various UWB system design techniques have already been proposed and some others are currently under investigation. Microwave tomography is formed of several UWB antennas where one antenna radiates the UWB pulses and rest of the antennas receive the scattered pulse from the object (Diaz-Bolado1 et al., 2011; Irishina et al., 2007). Unlike tomography, radar based microwave imaging consists of a transmitter and a receiver UWB antennas, where transmitter antenna emits UWB pulses at a time towards breast phantom and captures the scattered signal (by itself or other receiving antennas) (Fear et al., 2000). In this study, the recorded UWB pulses are forward scattered from the breast model, which is similar to the system proposed by Alshehri et. al. (2009).

1.2 Motivation and Problem Statement of The Research

Regular breast check-up is necessary and recommended by expert doctors for women community. Usually, people are reluctant to go for clinical check-up unless they feel physical problem. This is a common human nature to reduce hassle and cost.

Breast is an organ where abnormalities (tumors/cancer) can crop easily and silently due to its tissue structure. In general, benign tumor may exist longtime inside the breast tissue without (showing or feeling) any symptom to the patient. But the situation may become worst whenever it turns to deadliest malignant tumor rapidly. So, it is urged to develop a user friendly, handy, low-cost and automated non-invasive system for end users (domestic environment) for their breast self-checkup regularly and for early detection of breast tumor.

The existing systems are mostly operator dependent, complicated, heavy and implemented for clinical purposes only. None of the study has yet been done thinking about the end user for domestic usage. The feature of the proposed system includes simple, cost efficient, highly accurate, non-invasive and user friendly which can be used for household applications.

Microwave UWB imaging poses new challenges for early breast tumor detection. It requires a high resolution characteristics that can be achieved from the transmitting/receiving antenna. The desired antenna should have compact size, low distortion, and high directivity and gain (Abbosh et al., 2009; Adnan et al., 2010). But, the antennas so far designed for the microwave imaging system are not handy and have computational complexity with a less directive gain (Tiang et al., 2013). Some researches on antenna design (especially on UWB antenna) for breast tumor detection have also been done (Bourqui et al., 2010; Yu et al., 2009). These research works tend to design planar and small size UWB antennas since those are easy to implement as a base for an antenna array with several elements (Kanj et al., 2008). Also, the antenna size is comparatively large for household usage (Zhang et al., 2005). Towards the design of a handy, cost effective and having less computational complexity microwave imaging system, Alshehri has already proposed early breast tumor detection system using couple of transceiver antennas (Alshehri et al., 2009). But a set of commercial transceiver (Tx) and receiver (Rx) antennas were being used in Alshehri et al. study which may deteriorate the signal strength and directive gain. Therefore, the goal of this research is to develop a compact sized, low cost and bio-friendly UWB planar antenna suitable for cost effective, easily usable and handy breast tumor detection system.

For the development of the proposed system, some crucial factors also come in to account which are not defined in the previous microwave imaging studies. The facts are to chose optimum operating frequency and placement of transmitting (Tx) antenna from the breast tissue. So far, from previous researches it is not clear what type of scattering (i.e., forward or backward) suitable for tumor detection at a particular Tx antenna distance from breast model (denoted as d_{Tx}) over a certain frequency range. For dispersive tissue wave propagation, Tuovinen et. al. (2012) have investigated the reflection loss co-efficient (S_{11}) result for UWB planar antennas. In their study, radiating and reactive near field results are compared between dipole antenna and loop antenna. The position of both antennas is varied from the 0 mm to 30 mm. The diameter of their designed antennas are large enough for body propagations, but they did not measure transmission co-efficient, S_{21} to verify clearly the antenna performances. Also, the discrete ports used for their case is not realistic and practically implementable.

On the other hand, signal processing algorithms are used to usually process, digitize and analyze the received signal and detect the existence of any tumor tissues (if exists). The extracted featured signal values and pattern recognition are then processed for classifications. There exists a good number of pattern recognition methods for the received UWB pulses. Support vector machine (SVM) detection technique has already been used to classify only the tumor signature from mammographic image (Ireaneus et al., 2009). SVM does have remarkable performance in terms of classification between tumor affected and healthy breasts tissues (Zhi-Hang et al., 2013). But there exists a